SF2A 2018
P. Di Matteo, F. Billebaud, F. Herpin, N. Lagarde, J.-B. Marquette, A. Robin, O. Venot (eds)

FOLLOW UP OF THE GAIA ALERTS

W. Thuillot[1] and M. Dennefeld[2]

Abstract.
The operating mode of the ESA-Gaia space astrometry mission includes the possibility to trigger alerts towards ground based stations for the validation or follow up of transient events. We present a summary of this alert system and ground-based activity regarding both the detection of new Solar System objects or the detection of photometric transient events. It is important to have a wide coverage from the ground and for some of these alerts the amateurs can provide a useful contribution.

Keywords: Gaia, alerts, follow-up, asteroids, novae, transients

1 Introduction

The space astrometry ESA-Gaia mission is operating since July 2014 (Gaia Collaboration et al. 2016a,b) and has provided a huge amount of data with an exceptional precision, through a first data release, DR1, on September 14th 2016 (Gaia Collaboration et al. 2016a) then through a more precise and voluminous second data release, DR2, on April 25th 2018 (Gaia Collaboration et al. 2018). But other Gaia data are public and almost immediately accessible: the Alerts, a trigger to validate and follow up from the ground the transient events or the new Solar System Objects detected in space by the probe. In both cases data are distributed via web pages and towards networks of observers ready to react on alert. The amateurs can usefully participate in these activities.

2 New Solar System Objects

During the exploration of the sky by Gaia, thanks to a specific scanning law, moving objects are detected among plenty of light sources. Astrometric and photometric measurements are carried out and if the objects are not known previously, i.e. if their position does not match with the ephemerides, these measurements go to a fast pipeline (Tanga et al. 2016) for the data processing in the framework of the Gaia DPAC objectives. The role of this pipeline is to chain several such observations of the same object, then to trigger an Alert to call for ground-based observations. As Gaia is not able to monitor such detections, supplementary observations are necessary to avoid the loss of these unknown objects.

The triggering of SSO detection alerts began in November 2016, rather late after the start of Gaia operations, but in order to have a wide geographical coverage, we had set up a network as soon as 2010, the Gaia-FUN-SSO network (Thuillot et al. 2015), and trained the observers to react for alerts. Starting from the end of 2016, we were able to provide sky maps of the zones on web pages (at the address `https://gaiafunsso.imcce.fr` where the new objects can likely be retrieved from the ground.

These sky maps are built thanks to the propagation of a preliminary orbit of the detected new object. But the detection is done through several transits in Gaia's focal plane, which lasts only 40 secondes each time. These short arcs of orbit are processed with a statistical ranging method, the Monte Carlo Markov Chain (MCMC) method, which leads to a bundle of possible orbits (Muinonen et al. 2016), translating into zones of interest in the sky to retrieve the object.

[1] IMCCE, Observatoire de Paris, PSL University, CNRS, Sorbonne Université, Université de Lille, 77 Avenue Denfert Rochereau, 75014 Paris, France
[2] Institut d'Astrophysique de Paris, CNRS, Sorbonne Université, 98bis boulevard Arago, 75014 Paris, France

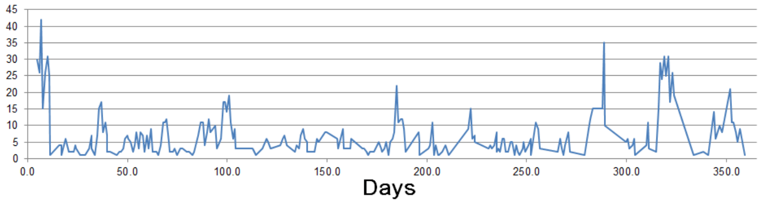

Fig. 1. Number of the alerts triggered on the 2016/11-2017/11 period

Between November 2016 and November 2017, more than 1700 alerts were triggered, representing an average of 5 alerts a day. But simultaneously we tried to tune the filtering parameters in order to avoid false detections and false alerts. Therefore in 2018, this number of alerts fell down to only around 5 alerts a week. Nevertheless this activity is still not regular but quasi periodic (Fig. 1), depending on the attitude of Gaia.

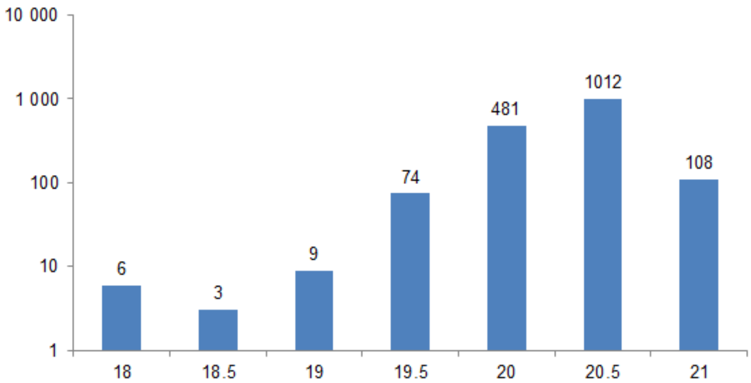

Fig. 2. Histogram of the magnitudes of the alerts during the 2016/11-2017/11 period

It was rather surprising to see that several alerts could be related to objects of magnitude as bright as 18 (Fig. 2). Nevertheless the bulk of alerts concerned objects of magnitude in the range 20-21. Consequently, telescopes with diameters as large as 0.6 m, or observing in tracking mode (tracking the object with its apparent velocity instead of the sidereal motion) can possibly retrieve the unknown object. Note that at this date, we recommand to the observers to reduce themselves their observations and then to send the astrometry to the Minor Planet Center, in addition to their feedback on our website. If they are the first to do that, they can therefore be registered as discoverers.

3 Transient events

Alerts other than Solar System Objects, based on photometric variability, are triggered thanks to a specific software developped in Cambridge (UK) and are published on the following web page: `http://gsaweb.ast.cam.ac.uk/alerts/`. For each event, basic data are provided, like time of discovery, magnitude change, finding chart, etc... and a plot of the photometric evolution if more than one point observed by Gaia is available. This helps to distinguish between variability of a previously recorded object, and the appearance of a new transient like a Supernova (SN). In addition, the low resolution spectra from the Blue Photometer (BP) and the Red Photometer (RP) are available also, unfortunately only in uncalibrated form, which makes them difficult to use for non-expert eyes. But some comments are introduced on the possible nature of the object, written by the experts of the Alerts Group who use those data also. Indeed, at the moment, a manual intervention is still necessary to select objects and avoid fake alerts (which would discourage observers from reacting on the ground), so this allows useful comments to be introduced (for instance, a type Ia Supernova (SN) is easily recognised thanks to its strong Si absorption line), but also explains the sometimes long delay between the detection by Gaia and the publication of the Alert. Improvements are on their way, and annual meetings allow the interested community to follow the evolution and provide useful suggestions. Details about the regular Alert meetings can be found at `https://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/`.

A number of Gaia Alerts concern possible SNe, which however require a ground based follow-up to be confirmed. What is particularly needed is a spectrum for classification, to be able to assign a type to the SN, and eventually recognise peculiar cases like under- or over-luminous SNe. More details can be found in the paper by Dennefeld (2018) in this volume. Spectroscopic classification of objects in the magnitude range 17-19, as provided by Gaia, requires at least a 2m class telescope, equiped with a low dispersion spectrograph (R $\sim$1000). While a higher spectral resolution might be sometimes useful, it would decrease the sensitivity accordingly. As no such instrument is presently available to the french community in the northern hemisphere, the completion of the new spectrograph for the OHP 1.93m telescope, MISTRAL, described in the paper by Adami et al. (2018) elsewhere in this volume, is eagerly awaited for. If no spectrum is available, long term photometric monitoring can be a rescue, as the type of a SN can be later recognised when a complete light curve is available, that is up to 2-3 monthes after maximum. In this case, Amateur Astronomers can play an important role, as photometry of 18-19 mag objects is easily accessible to telescopes much smaller than 1 meter in diameter. While two filters are preferable to assess the colour of the object, typically B and R (therefore avoid white light), the exact nature of the filter is of less importance, as the colour equation of the used system can be later established by using other, known stars in the field. An automatic calibration system has been developped by the Gaia Alerts Team (see `http://gsaweb.ast.cam.ac.uk/followup/`), and the observers only need to upload their data to the corresponding server (after having registered for the first use). As an example, it is this World-wide collaboration of many telescopes which has enabled the peculiar nature of Gaia16aye to be recognised, a microlensing event in front of a binary star (L. Wyrzykowski et al., in preparation): its full light curve can be seen on the previously mentioned Gaia Alerts site, and also on `http://sci.esa.int/gaia/58547-light-curve-of-binary-microlensing-event-detected-by-gaia/`.
Gaia is detecting many variables and transients, not only SNe, but also Novae, TTauri stars, FU-Orionis stars, Be stars, Cepheids, RRLyrae, RCorBor, etc..., all of which deserve a confirmation and the completion of their light curves. What is most missing is telescope time to accomplish all this: Amateur Astronomers can play an important role in this, each by selecting his/her type of object of interest, and so contribute to the development of this new, emerging branch of Astrophysics, the Variable Sky.

4 Conclusions

We invite amateurs to participate in the validation and follow up of transient events and objects detected and announced by Gaia. Concerning the detection of new Solar System Objects, observers can find all the information online on the Gaia-FUN-SSO web page at `https://gaiafunsso.imcce.fr`. Observers interested by the Gaia detection of photometric events can get information at `http://gsaweb.ast.cam.ac.uk/alerts/` Further information can also been obtained from the authors (thuillot@imcce.fr for astrometry of SSO or dennefel@iap.fr for photometric alerts).

Colleagues from the DPAC Gaia consortium, CU4 and CU5, must be acknowledged for the outstanding collective work regarding the Gaia alert systems. Our acknowledgements are also for many observers who participate in the ground based validation and follow-up. The outstanding developments achieved by the Gaia Alerts Team in Cambridge (S. Hodgkin, L. Wyrzykowski et al.) are gratefully acknowleged also.

References

Adami, C., Basa, S., Brunel, J., et al. 2018, ibid
Dennefeld, M. 2018, ibid
Gaia Collaboration, Brown, A. G. A. et al. 2016a, A&A, 595, A2 23
Gaia Collaboration, Brown, A. G. A. et al. 2018, A&A, 616, A2 28
Gaia Collaboration, Prusti, T. et al. 2016b, A&A, 595, A1 36
Muinonen, K. et al. 2016, Planet. Space Sc., 123, 95
Tanga, P. et al. 2016, Planet. Space Sc., 123, 87
Thuillot, W. et al. 2015, A&A, 583, 59